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Modelling operating area of condition and management of high strength bloating clay, stoving in a rotary kiln

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Abstract

High strength or construction bloating clay is widely used in construction operations especially in construction of roads, bridges, airfield pavement. It replaces crushed stone as an aggregate. Technology of high strength bloating clay requires essential changes in its stoving curve in comparison with the production of light bloating clay. It is shown that in order to solve an urgent construction problem of bloating clay release it is necessary to conduct monitoring of temperature pattern in a rotary kiln in several distinctive cross sections and conduct management of a kiln as an object with distributed constants with the use of several, especially three, concentrated control actions. The developed mathematical model of stoving process and methodology of computing experiment, exemplified by the 40×2,5м kiln, allowed to find operating areas of condition and management of an automated object, focused on bloating clay release with assigned strength.

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Keywords: high strength bloating clay,bloating clay production, rotary kiln, space of condition and management of an object, bloating clay temperature pattern.

1. Problem stating

Modernconstructionratesmakethereductionofcostoferectedbuildingsand building constructions, preserving the same strength and operational life time [1-5]. This can be achieved, particularly, by the use of high strength bloating

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clay (mark П200 – П350), instead of traditional crushed stone, that allow reduction of foundation thickness and used reinforcement [6]. It is required to identify the controllability envelope of high strength bloating clay stoving while regulating three control actions: kiln rotating speed $\omega_{\text{п}}$, charging the kiln q_3 with bloating clay adobe and burner heat rate $Q_{Г.}$

Increasing number of observable coordinates and control actions in technological process of bloating clay stoving in a rotary kiln as an object with distributed constants [7] allows showing it as multivariate structure (Fig. 1), where $\overline{X}$ – state vector of stoving process, identified by temperature values T_F, T_A, T_C of bloating clay in three distinctive cross sections of a thermal field of a kiln [8-10] across its length, $\overline{X} = [T_F, T_A, T_C]^T$; $\overline{U}$ – control action vector, $\overline{U} = [\omega_{\text{п}}, q_3, Q_Г]^T$; R – bloating clay strength; $\overline{H}$ – disturbation action vector, including moisture change vector of clay adobe w, composite index of clay properties γ_i of the first deposit [11,12], environmental temperature T_{oc} and others, $\overline{H} = [\Delta w, \gamma_{i,}, T_{oc}]^T$.

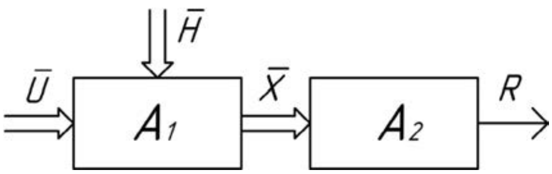

Fig. 1. Multivariate structure of management object.

Developed dynamic models of temperature pattern in a kiln [7,13] allowed to synthesize operatorA_1 [7], describing stoving dynamics in minor deviations relating to some work space of point A = ($\overline{U}_0, \overline{X}_0, \overline{H}_0$), which coordinates are identified by the values of output points, managing and disturbing actions for this point. Operator A_2, described in [14,15], connects the strength R of bloating clay with the parameters of stoving in cross sections F, A and C. Using mathematical model of [7] stoving temperature pattern of bloating clay and its related calculation model, created in SolidWorks software, it is possible to find (under the conditions of technological limits of bloating clay blowup [6,16]), operating area [17] in space of condition of $\overline{X}_э$ object, $\overline{X} \in \overline{X}_э$ determined as location of stoving curves inside constraint zones, and its relating operating area in control spaces $\overline{U}_э$, $\overline{U} \in \overline{U}_э$. The area $R_Д$ of attainable values of bloating clay values, identified by the boundaries of areas $\overline{U}$ и $\overline{X}$.

2. Problem solution

At the first stage of problem solution it is necessary to locate stoving curves on the OZT plane (fig. 2), corresponding to the production of bloating clay with a durability in R_{min} – R_{max} range. This area is limited above by the brake $O_1MB_вD_вE_в$, and below by $O_1NB_нD_нE_н$. Intrinsic curves O_1M and O_1N are set off to limiting curves (located in the upper and lower parts of the sought-off areas) from point O_1, focused on bloating clay production with R_{max} and R_{min} respectively.

In the blowup area the lower boundary $B_нD_н$ is identified by the minimum necessary blowup temperature, the upper $B_вD_в$ – by the clay fusion temperature [18]. The location of points $A_н$, $A_в$ is identified with the help of temperature and strength characteristics in accordance with the R_{min} and R_{max} values. The necessary condition for getting strong bloating clay is derivative validity dT/dt in the range of 5 up to 45 °C/min [6,19]. It is necessary to draw two rays from point $A_н$ until they intersect the rays $C_нB_н$ and O_1N with the slope of $tg\alpha = dT/dt = 45°C$ (corresponds with the rotating speed of a kiln $\omega_{\text{п}} = 0{,}26$), results in intervals $C_нB_н$, $A_нN$ and O_1N, the interval O_1N is represented as tangent to stoving curve 3 (at the speed of 0,26 rad/s). The rays from point $A_в$ are drawn analogic.

The second stage is represented as mathematical modeling of temperature pattern of a kiln in SolidWorks software, using certain combinations of vector parameters $\overline{U}$, from the discreet values $\omega_{\text{п}}$ = (0,08; 0,13; 0,26) rad/s; $q_з$ = (4,5; 8; 12) tons per hour; $Q_г$ = (33602; 16800; 11200) W/m^3. Set of stoving curves is a result of calculations (Fig. 2). It is specified that the major factors, influencing the presence of stoving curves in production zone, are $\omega_{\text{п}}$ and $Q_г$. The kiln charge $q_з$ to a lesser degree influence the presences of stoving curves in the limitation zone, that will allow achieving the maximum effective performance of high strength bloating clay stoving even at low values $\omega_п$ by means of charge increase $q_з$.

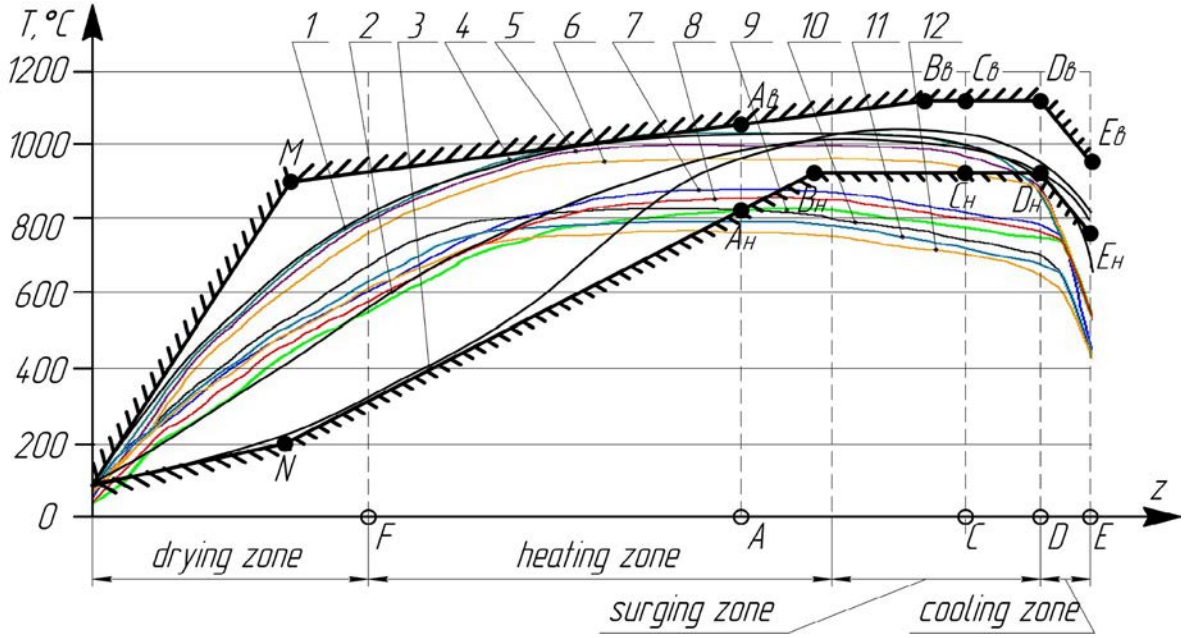

Figure 2 – Existence domain of bloating clay stoving.

3. Conclusions

The results of modeling will allow choosing optimal working pattern of stoving the kiln during the production of bloating clay of the certain strength R. The paper, in particular, shows that the best rational and economically effective way to stove the bloating clay, taken from the silt of Beskudnikovo deposit, should be carried out under the following parameters: speed of kiln rotation $\omega_п$ = 0,08 rad/s, adobe charge $q_з$= 12 tonnes per hour, and burner heating capacity 33602 W/m^3 $\geq Q_г >$ 29000 W/m^3.

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